Study Unit 8: B.3 — Learning Curves

(CMA Part 1: Cost Management — Cost Measurement, Planning, and Control)

🌞 Overview — What Is a Learning Curve?

The **learning curve** (or *experience curve*) shows that as workers gain experience producing a product or performing a task, **efficiency increases** and **time per unit decreases**.

In simple terms:

"The more you produce, the faster and cheaper you become."

⚙️ 1. Key Concepts

🔹 Efficiency and Experience

- Each repetition of a task improves efficiency.
- Labor time per unit **decreases** as cumulative production **increases**.
- Productivity improves rapidly at first, then slows and stabilizes over time.

💼 2. Use and Importance

Learning curve analysis helps management in:

- 📊 **Planning, Budgeting, and Forecasting**
- 💰 **Estimating labor costs** for production and contract bids
- 📈 **Cost control and performance evaluation**
- 🔧 **Setting standards** for new production processes

It estimates:

- Future labor hours
- Long-term cost behavior
- Expected cost reductions as output doubles

🧩 3. Two Learning Curve Models

Model	Description	Estimates	CMA Exam Focus
1️⃣ **Cumulative Average-Time Model**	Assumes the *average time per unit* declines by a constant rate each time cumulative output doubles.	Average time per unit for all units produced	✅ **Tested**
2️⃣ **Incremental Unit-Time Model**	Assumes the *time for the most recent unit* declines by a constant rate as output doubles.	Time for the last unit produced	❌ Not tested

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🔣 4. Mathematical Expression

For the Cumulative Average-Time Model:

$$\text{Estimated Cumulative Avg. Time per Unit} = \text{Time for 1st Unit} \times (\text{LC})^n$$

$$\text{Estimated Total Time} = \text{Cumulative Avg. Time per Unit} \times \text{Total Units Produced}$$

Where:

- **LC** = Learning Curve Rate (e.g., 80% = 0.80)
- **n** = Number of doublings (1→2, 2→4, 4→8, etc.)

📉 5. Understanding the Learning Curve Percentage (LC%)

- The LC% indicates how much time per unit is needed after each doubling of production.
- Example:
  - **80% Learning Curve** → When output doubles, average time per unit = 80% of previous average.

🧮 Example:
If the first unit takes 10 hours (LC = 80%):

Doubling	Units	Cumulative Avg. Time (hrs)
1st	2	$10 \times 0.80 = 8.00$
2nd	4	$10 \times 0.64 = 6.40$
3rd	8	$10 \times 0.512 = 5.12$

📊 6. Interpretation of LC Values

LC %	Meaning	Interpretation
100%	No learning	Time per unit remains constant
< 100%	Learning occurs	Efficiency improves
70%–90%	Normal realistic range	Common in most industries
≤ 50%	Impossible	Would imply producing double output in same or less time

✅ **Valid Range:**

$$50\% < \text{Learning Curve Rate} < 100\%$$

❗ Why LC ≤ 50% Is Impossible

- At **50%**, producing double output would take the **same total time** as the first batch — impossible.
  → $10 \times (2 \times 0.50)^1 = 10 \times 1 = 10 \text{ hrs}$
- At **49%**, total time < time for first unit — also impossible.
  → $10 \times (2 \times 0.49)^1 = 9.8 \text{ hrs}$
- Even **50.01%** gives an unrealistic second-unit time (≈ 0.002 hrs).

🧠 7. Understanding "Cumulative Average"

- **Cumulative:** All units produced so far
- **Average:** Total time ÷ Total units

$$\text{Cumulative Avg. Time per Unit} = \frac{\text{Total Time for All Units}}{\text{Total Units}}$$

Each time total production doubles, the cumulative average time per unit declines by the LC%.

🧮 8. Calculation Methods

Method 1 — Estimated Total Time Approach

$$\text{Estimated Total Time} = \text{Time for 1st Unit} \times (2 \times LC)^n$$

Then:

$$\text{Cumulative Avg. Time per Unit} = \frac{\text{Estimated Total Time}}{\text{Total Units}}$$

✅ Use when question asks for **total time**.
Saves time — step 2 may not be required.

Method 2 — Estimated Cumulative Average Time Approach

$$\text{Cumulative Avg. Time per Unit} = \text{Time for 1st Unit} \times (LC)^n$$

Then:

$$\text{Total Time} = \text{Cumulative Avg. Time per Unit} \times \text{Total Units}$$

✅ Use when question asks for **average time per unit**.

🧩 **Both methods yield identical results.**

📊 9. Example — 80% Learning Curve

Units	Doublings (n)	Formula	Total Time (hrs)	Avg. Time/Unit (hrs)
1	0	$10 \times (2 \times 0.8)^0$	10.00	10.00
2	1	$10 \times (2 \times 0.8)^1$	16.00	8.00
4	2	$10 \times (2 \times 0.8)^2$	25.60	6.40
8	3	$10 \times (2 \times 0.8)^3$	40.96	5.12

Interpretation:
As production doubles → average time per unit decreases → total time still increases.

📈 10. Calculating Time for a Block of Units

To find time for a *range* of units:

$$\text{Time for Units X–Y} = \text{Total Time (1–Y)} - \text{Total Time (1–(X–1))}$$

Then:

$$\text{Average per Unit} = \frac{\text{Time for Block}}{\text{Number of Units}}$$

Example:

- 1–4 units = 25.6 hrs
- 1–8 units = 40.96 hrs
- → 5–8 units = 40.96 − 25.6 = **15.36 hrs**
- → Avg./unit = 15.36 ÷ 4 = **3.84 hrs**

🧠 Note: Cannot calculate time for individual units (like unit 7) — only **blocks**.

🧮 11. Formula Relationships

Total Time=Average Time per Unit×Total Units\text{Total Time} = \text{Average Time per Unit} × \text{Total Units}Total Time=Average Time per Unit×Total Units
Average Time per Unit=Total TimeTotal Units\text{Average Time per Unit} = \frac{\text{Total Time}}{\text{Total Units}}Average Time per Unit=Total UnitsTotal Time
n=log₂(Total Units Produced)n = \log_2(\text{Total Units Produced})n=log2(Total Units Produced)

⚠️ 12. Special Case — No Learning

If LC = 100% → No learning effect:

10×(2×1.00)1=20 hrs (10 hrs each for 2 cars)10 × (2×1.00)^1 = 20 \text{ hrs (10 hrs each for 2 cars)}10×(2×1.00)1=20 hrs (10 hrs each for 2 cars)

If LC = 80% → Learning occurs:

- 1st car = 10 hrs
- 2nd car = 6 hrs
- Total = 16 hrs
- Avg. = 8 hrs per car

🚫 13. Limits of the Learning Rate

LC%	Outcome	Feasibility
≤ 50%	Impossible	Violates logic (same/less total time)
50.01%–99.99%	Possible	Practical range
100%	No learning	Constant time

📈 14. Practical Applications

Learning curve analysis is used to:

- Estimate **future labor time**
- Support **budgeting and forecasting**
- Assist in **cost estimation for bids/contracts**
- Evaluate **efficiency trends** and **performance**

When **overhead** is applied based on labor hours, costs may need segregation into:

- **Fixed costs** and **Variable costs**
  (using methods like **High-Low** or **Regression Analysis**)

🧭 15. Key CMA Exam Takeaways

✅ Learning curve = decline in average time per unit as production doubles
✅ Cumulative Average-Time Model = only one **tested** on CMA exam
✅ Two calculation methods (Total-first or Average-first) → identical results
✅ Valid LC range: **50% < LC < 100%**
✅ Realistic LC range: **70%–90%**
✅ Used for: budgeting, labor estimation, forecasting, and standard-setting